Viability of a rural electrification program in Peru

J. Hidalgo-Crespo[a, b], H. Bautista-Espinosa[c], J. Oviedo [d]
[a]Sciences pour la Conception, l´Optimisation (G-SCOP), Centre National de la Recherche Scientifique (CNRS), University of Grenoble Alpes, 38000, Grenoble, France
[b]Facultad de Ingeniería Industrial, Universidad de Guayaquil. 090150, Guayaquil, Ecuador
[c]Kazán Federal University. 420008 Kazán, 18 Kremlyovskaya street
[d]Universidad Estatal de Milagros, Cdla. Universitaria "Dr. Rómulo Minchala Murillo". Milagro, Ecuador
Corresponding author: jose.hidalgocr@ug.edu.ec

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Abstract. This research resumes the work carried out at the ACCIONA Micro Energy Foundation (FUNDAME) as part of the final internship and Master's thesis for the 2014 European Joint Master's in Management and Engineering of Environment and Energy Program (ME3). The internship took place in the Corporate Social Responsibility department of ACCIONA S.A. The internship consisted of improving the company´s business model to reach more isolated communities and effectuate preventive and corrective maintenance more sustainably. The step-by-step process used to implement this methodology in an economically sustainable manner using a fee-for-service model has been documented. In addition, the business model was evaluated to demonstrate its viability, impact, sustainability, and scalability during the systems' lifetime; improvements were also analyzed. Due to the distance between ACCIONA Micro energy Peru (AMP) and the users, the costs of installation and maintenance of these systems can be significant. The new methodology, which states the implementation of Energy Supply and Service Centers (ESSC), has the potential to decrease project and operational costs and sustain itself over time.

Keywords: Rural electrification, Socio-economic determinants, Poverty reduction, Fee-for-service model, Peru

Resumen. Esta investigación retoma el trabajo realizado en la Fundación ACCIONA Microenergía (FUNDAME) como parte de las prácticas finales y la tesis de maestría del European Joint Master's in Management and Engineering of Environment and Energy Programme (ME3 de 2014). Las prácticas se realizaron en el departamento de Responsabilidad Social Corporativa de ACCIONA S.A. Las prácticas consistieron en mejorar el modelo de negocio de la compañía para poder llegar a comunidades más aisladas y realizar el mantenimiento preventivo y correctivo de forma más sostenible. Se ha documentado, paso a paso, el proceso que se utiliza para implementar esta metodología de una manera económicamente sostenible utilizando un modelo de tarifa por servicio. Además, se evaluó el modelo de negocio para demostrar su viabilidad, impacto, sostenibilidad y escalabilidad durante el tiempo de vida de los sistemas, y se analizaron mejoras. Debido a la distancia entre ACCIONA Microenergía Perú (AMP) y los usuarios, los costos de instalación y mantenimiento de estos sistemas pueden ser significativos. La nueva metodología, que plantea la implementación de Centros de Abastecimiento y Servicio de Energía (ESSC), tiene el potencial de disminuir los costos operativos y de proyectos y sostenerse en el tiempo.

Palabras claves: Electrificación rural, Determinantes socioeconómicos, Reducción de pobreza, Tarifas por modelo de servicio, Perú.

1. INTRODUCTIÓN

Access to electricity is crucial to human development as it is, in practice, indispensable for certain basic activities, such as lighting and the running of household appliances like radios and television, and cannot easily be replaced by other forms of energy. Individuals' access to electricity is one of the clearest and most undistorted indications of a country's energy poverty status (GNESD, 2007).

Electricity access is increasingly at the forefront of governments' preoccupations, especially in Latin America. Therefore, many rural electrification programs and national electrification agencies have been created in this region to accurately monitor the needs and status of rural development and electrification. In Table 1, the latest availability of electricity access in the world is shown by region and country (GNESD,2007; IEA, 2011).

Table 1. Regional electricity Access

	Population without electricity millions	Electrification rate %	Urban electrification rate %	Rural electrification rate %
Africa	587	41,8	68,8	25,0
North Africa	2	99,0	99,6	98,4
Sub-Saharan Africa	585	30,5	59,9	14,2
Developing Asia	675	81,0	94,0	73,2
China & East Asia	182	90,8	96,4	86,4
South Asia	493	68,5	89,5	59,9
Latin America	31	93,2	98,8	73,6
Middle East	21	89,0	98,5	71,8
Developing countries	**1.314**	**74,7**	**90,6**	**63,2**
World*	**1.317**	**80,5**	**93,7**	**68,0**

From: IEA (2011)

Peru is a country of extreme diversity, both in its geography and in its citizen's socioeconomic conditions. This makes it a challenge for the Government of Peru to extend access to basic infrastructure services, including electricity, to the dispersed population living in rural areas. Plans and goals have been in place for rural electrification since the early 1970s, but by 2005, only 39 percent of rural households had electricity service. Peru has one of the lowest rural electrification rates in Latin America. An estimated 6 million people in the predominantly poor rural areas of Peru did not have access to electricity in 2005.

Various organizations have been engaged in rural electrification. Major organizations in the central government are the Ministry of Energy and Mines (MEM), Ministry of Education, Ministry of Public Health, ADINELSA, FONCODES, and PRONAMACHCS, while in the local administration, regional governments have been involved. Others include power supply companies, NGOs, and non-profit organizations such as ACCIONA Micro energy.

The main regulatory body in the energy sector is the Supervisory Agency for Investment in Energy (OSINERG). It is responsible for setting electricity tariffs, as well as supervising and monitoring technical regulations in the energy sector. OSINERGG oversees the Electric Social Compensation Fund (FOSE), one of the main drivers of rural electrification projects in Peru.

The FOSE provides electricity subsidies to low-consumption electricity users in both urban and rural areas. For rural electricity users consuming less than 30 kWh/month from distributed off-grid systems, the subsidy covers 62.5% of the electricity service cost (Meier, 2010). The FOSE subsidy significantly lowers the economic barriers to

connecting rural customers to electricity services and is a key component in FUNDAME´s rural electrification operations in Peru.

To develop the fee-for-service model, FUNDAME creates local non-profit micro-enterprises to carry out and manage rural electrification initiatives in countries with very low- access to grid electricity. The use of micro-enterprises creates a sense of local ownership and involvement in projects and fosters capacity building in local communities, that finally leads to an improvement in the long-term sustainability of the projects.

The fee-for-service model allows access to electrical services at an affordable price, which is imperative for reaching low-income customers who are located far away from the electrical grid. The fees collected by the micro-enterprise cover the costs of long-term operation, maintenance, and parts replacement (Barkat, 2005; Solargis, 2022). In this manner, the sustainability of the project is guaranteed for a period of 20 years.

In Figure 1, the solar potential in South America can be seen. There's a huge potential for this kind of energy, particularly in Peru. It has been estimated that Peru has favorable conditions for the development of solar energy projects (Solargis, 2022). However, the country's solar potential has not been exploited yet. In the mountain ranges located in the South, solar energy reaches average levels above 6 kWh/m^2/day, which are among the highest worldwide. On average, solar radiation across a horizontal area of the Sierra is more than 5 kWh/m^2 and in the forest ranges from 4 to 5 kWh/m^2.

In a study done by the Ministry of Energy and Mines (MEM), it is estimated that there are just over 66.000 photovoltaic solar energy systems installed in Peru, providing a total capacity of approximately 4,7 MW being Cusco, Loreto, Cajamarca, Piura, and Ucayali the regions with the largest number of these systems (Eisman, J. 2012.)

The electrification of isolated rural communities with renewable energies (photovoltaic) is the option chosen by the ACCIONA Micro Energy Foundation to facilitate access to basic electricity services in rural communities which don´t have any government electrification plans for at least the next ten years (ACCIONA Microenergía Peru 2011; ACCIONA Microenergía Perú, 2012).

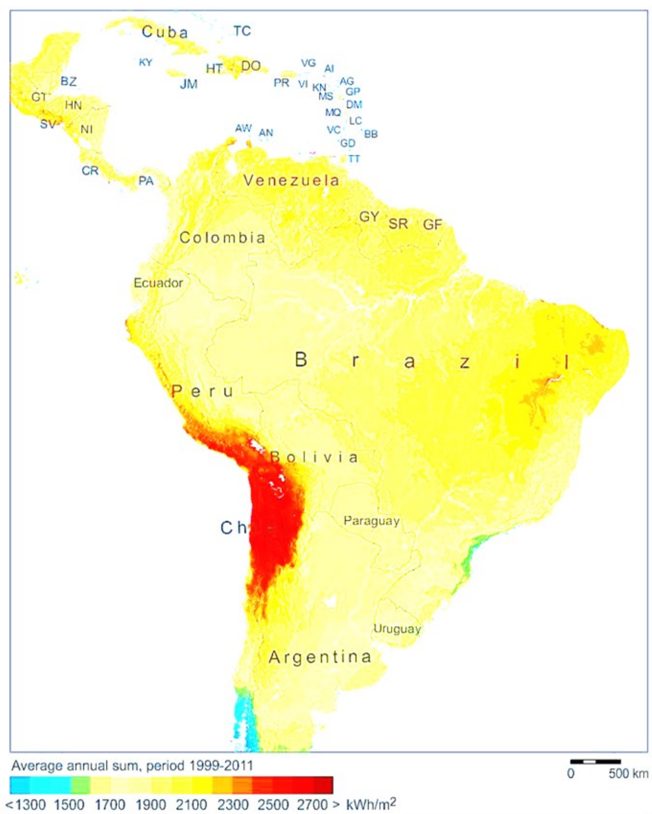


Figure 1. Solar irradiation in Peru. (Solaris, 2021)

Electrification enhances the quality of life at the household level and stimulates the economy at a broader level (IEG 2018; Rubtzov et al., 2022). The immediate benefit of electrification comes through improved lighting, which

promotes extended hours of study and, in turn, contributes to better educational achievements. Lighting can also benefit other household activities, such as sewing by women, social gatherings after dark, and so on.

Replacing inefficient kerosene lighting with electric lighting or other clean alternatives can rapidly achieve development and energy access goals, save money and reduce climate warming. Kerosene costs can be a significant household expense and subsidies are expensive. New information on kerosene lamp emissions reveals that their impacts on the climate are substantial. Robust and low-cost technologies to replace the simple wick and other kerosene-fueled lamps exist and are easily distributed and scalable. Improving household lighting offers a low-cost opportunity to improve development, cool the climate, and reduce costs.

Previous initiatives of electrification using photovoltaic systems have been based on a project model. This means that the equipment is donated or given value to the users, and they are later trained to provide basic maintenance to this equipment, but there is no follow-up from the donating entity.

The problem facing these initiatives is the lack of sustainability and affordability of these solar home systems. First, the systems do not work throughout their total useful life (usually 20 years); second, maintenance and spare parts costs are very high, so the users do not have sufficient knowledge and means to acquire them on their own.

Keeping this in mind, FUNDAME developed a service provision model, since "it is not enough just to bring the electricity to isolated communities, but also the after service" (ACCIONA Microenergía Peru , 2011).

1.1. Impacts on education

Worldwide, 75 million children fail to complete primary school, either because they drop out in the early years or because they never get the chance to attend school at all (OECD/IEA. 2010). Children in rural areas, especially girls, often spend a great deal of time on basic subsistence activities, such as the collection of firewood for lighting and cooking. Although access to electricity does not have an immediate impact on educational levels, it can influence learning performances by providing adequate lighting for children to spend more time studying and reading later in the evening. In addition, it brings with it the possibility of gathering information through radio, television, and other technologies.

1.2. Impacts on gender

According to the United Nations Population Fund's report, State of World Population 2008, there is still a strong link between poverty and gender. 60% of the people suffering from poverty are women. In the traditional gender-specific division of labor, household activities are predominantly the duty of women. They are subject to various health risks connected with cooking, such as chronic respiratory diseases, pneumonia, or eye infections that are caused by indoor air pollution (MEM, 2011; UN, 2005).

Electricity also supports income generation. It has made it possible for women to do some of their housework after dark, so they have time to do productive work during the day.

1.3. Impacts on health

The health risks of using kerosene for lighting are associated with the release of much higher levels of emissions harmful to health and climate change, for example, small panels and solar photovoltaic power flashlights (UN, 2005; UNDP/World Bank 2002).

Inhalation of vapors by burning kerosene, wood, and candles can cause confusion, cough, dizziness, headaches, sore throats, and loss of consciousness. The World Health Organization has shown that every year around 1.5 million deaths are caused by indoor pollution from traditional ways of lighting.

More generally, small particles and other indoor smoke contaminants, swell airways and lungs, triggering immune responses and reducing the oxygen-carrying capacity of the blood. There is also evidence of links between indoor air pollution and low birth weight, tuberculosis, ischemic heart disease, and nasopharyngeal and laryngeal cancers.

1.4. Impacts on the environment

Most sources of energy are derived from our natural surroundings, including fossil fuels, biomass, sun, wind, and water. Without sound, sustainable management, the production, and consumption of energy have severe effects on the local and global environment. Deforestation, land degradation, desertification, and air pollution from excessive greenhouse gas emissions affect southern hemisphere people most severely (World Bank, 2008).

Modern and clean energy services, characterized by improved efficiency, and the use of clean energy sources help to ensure environmental sustainability. They also reduce biomass demand and, therefore, slow down forest destruction. They reduce greenhouse gas emissions and land and water acidification.

Photovoltaic installations, such as solar home systems, do contribute to environmental sustainability by decreasing the demand for kerosene and gasoline. However, special attention must be paid to the proper disposal of solar-charged batteries, a process that is still in its infancy in many project regions.

1.5. Additional impacts

The link between electricity and sustainable development has several additional benefits, such as:

- Improved potential to access information and entertainment. - One way in which rural electrification can have a positive social impact is through improved media access. Radio and television may have an impact on various aspects of social life. Besides their use for entertainment, radio and television can be regarded as possible agents of change in the sense that they can contribute to education through educational programs. They supply people with information about what is going on in their country and the world, and they increase people's knowledge about health and gender-related topics (Che et al., 2021; Bautista et al., 2022; Dominko, P. & Slabe-Erker, R., 2021).
- Increased social activity. - An additional positive impact that lighting energy has is an increase in safety and security in rural households, as it discourages theft and robbery. It increases a sense of safety within homes, and it can also make people feel safer moving around.
- Keeping the population from migrating to urban areas. - Advocates of this idea hold that access to modern energy services improves the quality of life and diminishes reasons to migrate; because it improves socio-economic development and raises people's expectations. However, evidence for such a relationship is ambiguous.
- An effect on people's social position in their communities.- Such people often acquired a reputation for being innovative and are thought to contribute to community development, thus they enjoy the appreciation of many families (Bautista et al., 2022; Nie P. Li Q. Sousa-Poza. 2021)

FUNDAME's projects address social, economic, environmental, and integrated problems with an innovative approach going beyond the purely technological field. Since its creation in 2008, FUNDAME has installed 3.000 systems in Cajamarca, Peru, reaching economical sustainability. An additional 900 systems will be installed by the end of 2019 progressing towards its goal of installing 10.000 solar home systems by 2025;

FUNDAME's innovative solution has already been developed and successfully tested at the pilot level. So, its ability to be replicated on a larger scale has been demonstrated, always looking for a positive and significant impact on the lives of the most disadvantaged people and social cohesion.

FUNDAME has been operating successfully for more than 6 years, although its work has not been completely detailed and formally documented. The objectives of this thesis are:

- To promote and record this innovative model for rural electrification.
- To prove, based on the knowledge, competitiveness, and experience of FUNDAME and AMP, that it is sustainable, equitable, and respectful to human development, human rights, gender equality, and the environment.
- To create a detailed and complete description of Peru's business model and the methodology being employed.
- To generate ideas on how to improve the existing model.

To register Peru's business model efficiently, it was necessary to do background research to become familiar with the foundation's operations and with the process being used to carry out the electrification using solar home systems.

2. MATERIALS AND METHODS

To facilitate the implementation and sustainable operation of rural electrification projects, the ACCIONA Micro Energy Foundation (FUNDAME) has developed an original methodology for carrying out its work in Cajamarca, Peru.

This methodology identifies all of the necessary phases of project formulation and includes actions and process explanations that must be completed during each phase. The primary phases used in the formulation of this project are Innovative Solution Presentation, Pilot or Experimental Project, Application of the Solution, and Replicability Demonstration.

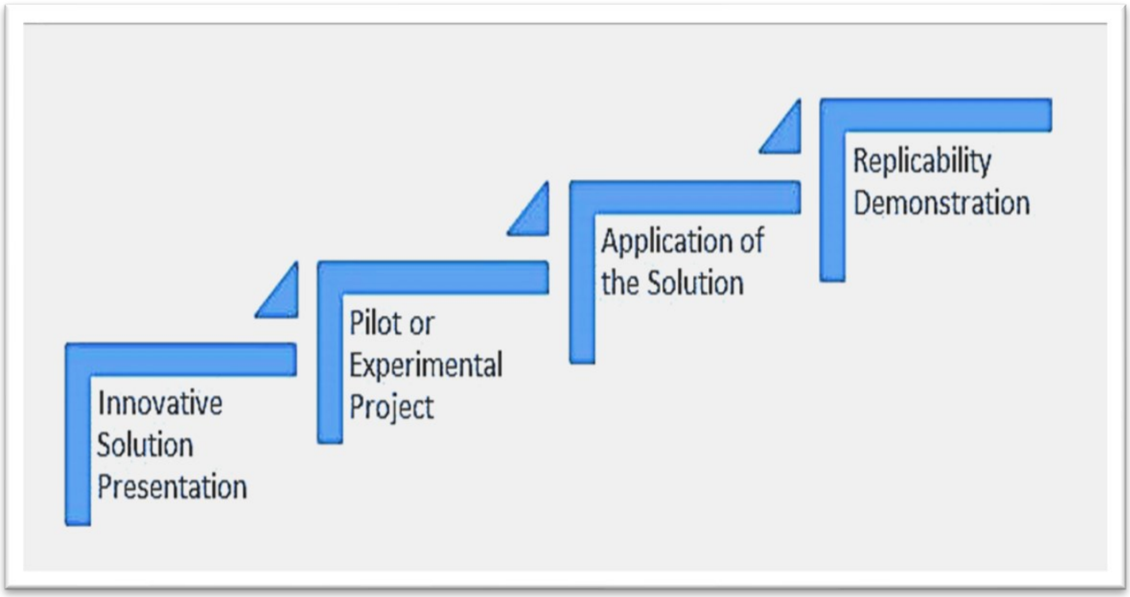


Figure 2. Stages of project formulation

Given the situation in the region of Cajamarca, FUNDAME designed the project "Luz en Casa" (Light at Home), focusing on electricity provision to rural communities in this area. This initiative has, as the main objective, the electrification with Solar Home Systems (SHS) of 10,000 households until 2020, which are outside the grid extension plans that have electricity near the area, have not benefited.

The solution directly addresses the rural electrification lack of affordability and sustainability problem with renewable energy through an innovative service model, which is being implemented by ACCIONA Micro energy Peru, with the financial, technical, and management support of ACCIONA Micro Energy Foundation.

The user pays a monthly membership fee for service. It´s less than the monthly average energy cost for families in these rural areas. The user does not pay any extra value in matters of preventive and corrective maintenance.

Photovoltaic Electrification Committees (PEC) are implemented in each community where the SHS are installed and serve as mediators between AMP and the users. The system installation, changes, cuts, reconnections, and maintenance incidents attendance are carried out by the Energy Supply and Service Centers (ESSC).

Users can report incidents to the PECs or directly to AMP. The key to the solution success can be divided into three elements:

- The dialogue with public authorities and regulatory bodies.
- The service delivery model.
- The design of technological and organizational innovations.

2.1. Profiles of the groups to which the solution benefits

The recipients and final beneficiaries are rural families living in isolated rural areas (average altitude, 3.000 m. above sea level) from different Cajamarca provinces in Peru. The municipalities can also be considered recipients because they aim to improve the living conditions of their people, especially the access to electricity services.

According to a socio-economic study, conducted in 2009 by AMP through surveys in the area, the target population has an average monthly income of 150 PEN (approx. USD 50) and spends on alternative energy items (candles, kerosene, and batteries) 15 PEN (about USD 5). They also have 4 to 5 children and live on agriculture and livestock, and, to a lesser extent, mining.

Almost 81% of the beneficiaries live below the general poverty line equivalent to a daily income per capita of less than USD 10. Most households use candles or kerosene lamps to light their homes. A danger associated with

kerosene has to do with pollution: pouring or releasing kerosene into the environment can poison animals and ecosystems and create potential fire risks. Also, the storage of these fuels represents a potential risk of accidental poisoning, especially when there are children in the house.

Using kerosene for lighting is associated with pollution and is harmful to health and the climate.

2.2. Benefits to the households

Some of the improvements identified in the communities where the systems are installed are mentioned below:

- Efficient lighting enables to increase in working time during the day by about 4 hours (up to 50 % of the workday) which enables the generation of additional revenue.
- Lighting allows reading and homework for children at school age; therefore, it affects education.
- Lighting reduces fire risks, and it lessens burns and eye and lung diseases caused by inhalation of fumes.
- It facilitates the use of radio, television, and mobile phones that promote social interaction.
- It enables money saving for a large part of the target population since the monthly social tariff is less than their monthly average cost for energy consumption.

Furthermore, these actions enhance the direct and indirect beneficiaries' capabilities as follows:

- Users are trained in technical knowledge (basic concepts of electricity and mechanics) and SHS management (proper use of the systems).
- They develop organizational (collaborative and disciplinary roles), technical (basic maintenance), and management (collective management and communication) capabilities that reinforce Photovoltaic Electrification Committees.
- They reduce travel time used to buy candles, kerosene, or batteries.
- In summary, the Light at Home program improves the living conditions of the beneficiaries and develops organizational, technical, and management capabilities at local, municipal, regional, and national levels.

2.3. The innovative character of the solution in terms of service, process, and strategy

The service delivery model of AMP differs from others because of its sustainability over time, in addition to the generation of technology entrepreneurs and job opportunities.

Some innovative solutions are:

- The installation of Solar Home Systems.
- To extend the use of social tariffs to isolated communities.
- To participate in the creation, in 2009, of a service agency called ACCIONA Micro energy Peru (AMP).
- An affordable monthly service for all residents of these communities: a socio-economic study is conducted in each community, with support from universities and municipalities. Their main purpose is to know the level of income per family and their spending capacities on energy substitutes and, thus, the value of the monthly membership fee is determined.
- To engage communities by creating Photovoltaic Electrification Committees (PEC). Each PEC is composed of at least 3 people, where one of them is a woman, and are constituted to take local functions such as:
  - Collection of service fees.
  - Inspection of the system's good use by the users.
  - Equipment monitoring.
  - Intercommunication with AMP.
- To create Energy Supply and Service Centers that train local technicians.
- To modify the regulatory environment.

2.4. Advantages over other similar solutions

- SHS sustainability over time: Solar panels have a 20-year life use and auxiliary equipment (batteries, charge controllers, electromagnetic lock, and other consumables) can be replaced.
- Service Company (AMP) sustainability: Positive cash flow and ability to purchase equipment and spare parts and provisioning money to purchase new equipment and train new technicians.

- Access to remote locations through Energy Supply and Service Centers (ESSC) implementation. These are responsible for installing new systems in remote households.
- Acceptance and Recognition of AMP by the Peruvian Regulatory Framework as a nonprofit company providing electrical services with renewable energy.

2.5. Impact on development

Electrical energy is a facilitator of household development, and the impacts can be divided into five elements:

Lighting

The lumen (lm) is the unit coined by the International System of Units for measuring luminous flux, a measurement of light power emitted by the source. Households use candles or kerosene lamps as the main source of lighting. The number of lumens of both is low compared with that of a LED (Table 2) that is delivered as part of the system.

Table 2. Lumens by type of light source

Source	Lumens
Candle	12
Kerosene Lamp	8-40
LED Bulb	180

The photovoltaic system can provide 4 hours of light with three LED light bulbs working at full load. This time can always be extended if a single LED bulb is used. Light time depends on the number of charges which are connected simultaneously to the systems.

Education

Although access to electricity has no immediate impact on educational levels, it can influence levels of learning by providing adequate lighting for children to spend more time studying and reading.

The poor quality of light and noxious fumes from kerosene lamps impedes children's possibility to study effectively. The light provided by the system is bright enough to provide longer and more efficient hours of study, which directly lead to greater learning and better education results (ACCIONA Microenergía Perú, 2012). Additionally, parents can supervise the education of their children after working hours at night.

Economic

The use of panels for lighting has enabled beneficiary households to reduce the purchase of candles and batteries. Candles are the preferred source of lighting, but these households also use batteries to operate flashlights. Thanks to solar panels, a greater proportion of women can weave garments for their family members. These garments can also be sold, which translates into additional income for the family.

Synergy with communication technologies

In addition to improving home lighting, solar electrical systems can be used to power communications systems such as radios, TVs, and mobile phones to allow the integration of families into the information society.

Energy Supply and Service Centers (ESSC)

The implementation of this project promotes the production of inclusive businesses. Since the establishment of AMP in 2009, 26 technicians have been trained and formalized in the Peruvian regulatory framework, and they have installed a total of 2,400 systems and attended photovoltaic incidents reported by the users to AMP.

Sense of ownership of the beneficiaries and the local government

It is of absolute importance to provide the communities and local government with a high sense of ownership and to commit the user to the correct management and care of their systems. This can be achieved by assigning responsibilities and giving power to some individuals within each community. Some ways to accomplish this sense of ownership are:

- To meet with the local authorities during the location identification, communicate the initiative, and anno, once the communities about awareness meetings.
- During these meetings, potential users hear about system benefits, and terms of service so the final list of interested people could be collected.
- Creating Photovoltaic Electrification Committees is a way to make communities participate in decision-making and influence the project's sense of importance.
- The implementation of the Energy Supply and Service Centers allows entrepreneurial technicians to undertake inclusive businesses. Each technician is responsible for their finances, creating a greater sense of ownership.

Both for the installation of new systems and the implementation of the ESSC, AMP has meetings to introduce FUNDAME to the local and municipal authorities. Cooperation agreements are signed with these entities so that there could be better coordination and complementarity during project implementation.

2.6. Alignment with Peruvian public policies

The National Rural Electrification Plan (NREP) 2012-2021 was prepared by the Ministry of Energy and Mines (MEM) through the Directorate General of Rural Electrification (DGRE). Its development has been conducted by the great transformation that drives the current Peruvian government, which aims to achieve electricity universal access to all Peruvians in late 2025.

Rural electrification has, as its goal, energy, and social inclusion. In particular, homes could get access to basic electricity services, thus solving the huge gaps in infrastructure access between urban and rural areas, while incorporating beneficiaries into the market, for consumption and development achieving social inclusion and reducing poverty.

That is why the DGRE/MEM has designed a plan for the next five years that will drive the implementation of electrification works that will achieve the target set in the medium-term goals while implementing efficient and productive electricity production optimization along with an increase of beneficiaries.

For the formulation of this plan, the DGRE/MEM has decided with other public and private entities, regional and local governments, and electricity distribution companies, to harmonize its contents with the respective Local and Regional Development Plans to create the notion of a joint work of various levels of government as well as public and private entities.

One of the agencies involved in this plan is FUNDAME through AMP. Since the Cajamarca region has the biggest energy poverty in the country, the Light in the Home project, scheduled until 2020, expects the electrification of 10.000 homes in the region, contributing to achieving the NREP objectives.

Before the normative development of non-conventional renewable energy rural electrification, conducted in 2010 by the Ministry of Energy and Mines and OSINERGIM, the isolated communities without the foresight of being electrified by grid had two options:

- Either to stay in the darkness with candles or kerosene lamps.
- Or to buy their PV system to have quality lighting.

While users of the grid with low consumption saw its rate reduced by the Electric Social Compensation Fund (FOSE), the purchased PV systems did not have any type of financial or maintenance aid. In 2011, after a long process of accreditation, AMP becomes the first exclusive provider of basic PV electrical service, accessing the subsidy and being able to reduce the social tariff that the users need to pay.

3. RESULTS

FUNDAME through its project "Light in Home", aims to provide electrification to 10,000 families by 2020 in the region of Cajamarca, Peru. To achieve this goal, they participated in the creation, in 2009, of a non-profit organization called AMP under the Peruvian regulatory standard, whose tasks are:

- Identify isolated rural communities.

- Conduct socio-economic studies of these communities.
- Create Photovoltaic Electrification Committees in each community served.
- Deal with local government agencies.
- Select and train local people and formalize them as technology entrepreneurs.
- Install the Solar Home Systems.
- Give preventive and corrective maintenance.
- Artifact Sales Service.
- Collect fee payments from the users.

During the first project feasibility study conducted by FUNDAME in 2009, it was revealed that the economic sustainability of AMP could be achieved once installed 3.000 systems, thanks to the fees paid by beneficiaries and scale economies.

That is why the pilot project objective was to achieve AMP economic sustainability by installing 3.000 systems. This pilot project was developed in three phases 2010, 2012, and 2013.

- In the first phase, 610 SHS were installed in November 2010 in the districts of San Pablo, Namora, and Tumbadén in the department of Cajamarca. The initial financing of the systems and installation was led by the ACCIONA group, who made this transfer as a donation.
- In the second phase, 700 SHS were installed in the districts of Cachachi, La Encañada, Namora, San Pablo, Ichocán, and Tumbadén in Cajamarca. This project was submitted to the Ministry of Energy and Mines of Peru for co-funding with rural electrification funds from the World Bank.
- In a third phase, 1.700 SHS were installed with a loan made to the Interamerican Development Bank (Banco Latinoamericano de Desarrollo) achieving a total of 3,010 systems, reaching economic sustainability and fulfilling the goal of this pilot project.

During this time, AMP has trained 26 local technicians that were responsible for the installation of the SHS. These technicians have been formalized under the Peruvian government regulations as technology entrepreneurs.

3.1. Description of the obtained results

To this date, 3.010 solar home systems have been installed in 87 communities in the region of Cajamarca, Peru, benefiting 3.000 families, and more than 15,000 people and AMP has achieved economic sustainability. In 2011, AMP became the first provider of basic electricity with photovoltaic energy in Peru and gained access to a cross-subsidy from the Social Power Compensation Fund (FOSE).

The Inter-American Development Bank (IADB) approved on August 27, 2012, financing of a million dollars to ACCIONA Micro energy Peru, to acquire 1.700 solar home systems (SHS), as part of the pilot project, and also donated an additional USD 300.000 for technical assistance. This funding proves the sustainability of AMP's business model.

An agreement with ACCIONA Micro energy Peru was also signed. They would, besides participating in the project as a local partner, take over the system operation and incorporate it into their service fee business model, ensuring economic sustainability.

3.2. Application of the solution

According to the survey conducted by the Multilateral Investment Fund (MIF) of the Inter-American Development Bank (IADB), the inhabitants of the beneficiary communities continue to use, although in less proportion, batteries for their radios. "Electrical Energy is just a mean to development". (ACCIONA, Microenergía Perú, 2012)

Some of the lessons learned during the pilot phase are:

- There is a lack of highly efficient devices enabled and adapted to the voltage and power of the systems.
- Distance is too long between AMP and the communities, exponentially increasing the time needed to attend to user needs.
- An efficient telecommunication system between the technicians, AMP, and FUNDAME is needed.

To reach the system's full potential, FUNDAME seeks to further develop the idea of the Energy Supply and Service Centers to meet user needs. The ESSC will function as micro-franchises of AMP and among their duties will be:

- The attendance of incidents reported by AMP and the users: Modifications, Maintenance, Cuts, and Reconnections.

- Installation of new systems.
- Sales of artifacts to users: radios, televisions, and light bulbs, among others.

For this, FUNDAME developed a financial model to verify the feasibility of each ESSC, depending on the number of systems they'll address, the number of incidents and changes they'll attend per month, and the annual planned sale of artifacts. Also, FUNDAME will develop the funding model for the ESSC to acquire the artifacts, with the help of a financial institution.

4. DISCUSSION AND CONCLUSIONS

AMP has reached its economic sustainability, with the implementation of the pilot project, operating and maintaining the 3.000 pieces of equipment installed so far, for almost 3 years. This is a strength and quality test of the service model AMP demonstrated that Energy Supply and Service Centers can be implemented.

Thanks to the training planned for the technicians, they have acquired technical, managerial, and financial skills that will allow their business to take off sustainably. FUNDAME has included the creation of a funding system for the ESSC and the identification of a microfinance institution to provide them with good loan terms as part of its planning,

The ESSC is estimated to reach financial sustainability after the first year of implementation. AMP will continue to monitor each ESSC through bimonthly visits during the first year.

Along with the acquisition of artifacts for sale to users adapted to the PV systems, the full potential that the systems can generate will be reached. The finance system that will be created by FUNDAME includes microcredit to users, so they can purchase these devices to connect to their systems.

FUNDAME will identify and participate, when relevant and appropriate, in scientific networks, political or otherwise, that may be of benefit to program implementation through a lessons-learned base. The program will identify, analyze and share lessons learned that might be beneficial in the future design and implementation of similar projects. The identification and analysis of learned lessons is an ongoing process, and the need to communicate such lessons as one of the central contributions of the program is required to be completed at least once every 12 months until 2020.

After the installation of the 900 systems programmed for 2014, AMP will have a total of 4.000 operational systems in the department of Cajamarca. FUNDAME will continue searching for financing to purchase and install the remaining 6,000 systems to achieve the goal of 10,000 Solar Home Systems by 2020.

Once the feasibility of the Energy Supply and Service Centers is verified, the model can be replicated to attend to the whole 4.000 systems and the next 6.000 to be installed.

A detailed methodology of the process that FUNDAME used to formulate a rural electrification project in Peru was created. This article contains a detailed accounting of the step-by-step processes used in each phase of the project formulation. Some options to improve the methodology were also explored.

FUNDAME realized that the main problem with the current rural electrification initiatives is the lack of user tracking. Even though the users are trained in the main functions of the solar systems and also give preventive maintenance, this is not enough to maintain the systems operative, due to the lack of knowledge about spare parts and the high costs for a single buyer.

This is the reason why FUNDAME was created, in 2009, by a non-profit company named AMP, to provide an after-installation service to the communities in the department of Cajamarca. AMP's main functions would be:

- Installation of new solar home systems.
- Preventive and corrective maintenance.
- Formation of technicians.
- Collection of the monthly service fee.
- Spare parts replacement due to end of useful life.

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The author(s) declared no potential conflicts of interest within this research, authorship, and/or publication of this article.

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